

RADIATIONS FROM HOT NUCLEI

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Abstract

The investigation indicates that nuclei with excitation energy of a few hundred MeV to BeV are more likely to radiate hot nuclear clusters than neutrons. These daughter clusters could, further, de-excite emitting other hot nuclei, and the chain continues until these nuclei cool off sufficiently to evaporate primarily neutrons. A few GeV excited nuclei could radiate elementary particles preferentially over neutrons.

Impact of space radiation with materials (for example, spacecraft) produces highly excited nuclei which cool down emitting electromagnetic and particle radiations. At a few MeV excitation energy neutron emission becomes more dominant than gamma-ray emission and one often attributes the cooling to take place by successive neutron decay. However, a recent experiment [1] studying the cooling process of 396 MeV excited ^{190}Hg casts some doubt on this thinking, and the purpose of this investigation is to explore the possibility of other types of nuclear emission which might out-compete with neutron evaporation.

Our earlier investigation [2] on the fragmentation of ^{16}O by protons done in connection with cosmic elemental abundance studies indicates that a significant part of fragmentation occurs through a statistical process that envisages formation of an intermediate excited compound system. This decays to two fragments. The study done for a few tens to a few hundreds of MeV incident proton energies reveals two interesting points (Table 1): (a) emission of nuclei heavier than neutrons, protons, and alphas may be more probable, and (b) these nuclei are emitted preferentially in excited states which may further emit gamma rays and/or other nuclear radiation.

We extend the study to calculate the emission probabilities of hot heavy nuclei relative to neutrons from 396 MeV ^{190}Hg . At this excitation, the transmission coefficient in the final channel between a daughter and the parent could be set to one [3], and the decay probability, $P(I, U)$ is simply governed by available phase phase and given by

$$P(I, U) \sim \int \rho_1(U_1) \rho_2(E - U_1) dU_1 \quad (1)$$

where U and U_1 are, respectively, excitation energies of a parent and one of its

daughter nuclei. E is the total available energy which is also the domain of integration. ρ_1 and ρ_2 are the level density functions of two final fragments. We have evaluated equation (1) using Fong's approximation [4] for the emission of neutrons and other nuclei and present some typical results in Table 2. We find that (a) emission probabilities of many heavy clusters exceed that of neutrons by several orders of magnitude, (b) these clusters are preferentially emitted in excited states, and (c) with considerable kinetic energies. These reactions are exothermic since Q values are positive. These hot emitted clusters could further radiate other heavy nuclei, for example, Gd in Table 2 has enough excitation to radiate C, O, etc. This "chain" continues until one of the products cools off sufficiently to emit preferentially neutrons.

At 4 GeV excitation of ^{190}Hg , the Λ and Δ emissions compete with that of neutrons; however, hot cluster radiations dominate.

1. S. Beierdorf, R. A. Esterlund, M. Knaack, P. Petzelt, F. P. Hessberger, V. Ninov, and A. Luetngen, Preprint (1992).
2. B. Compani-Tabrizi and F. B. Malik, J. Phys. G.: Nucl. Phys **8**, 1447 (1982).
3. F. B. Malik, Invited talk at 2. international conference on atomic and nuclear clusters, Greece, July 1993.
4. P. Fong, Statistical Theory of Nuclear Fission (Gordon and Breach, New York, 1969).

Table 1: Decay Widths in MeV of ^{17}F to Fragments Listed in Columns 2-5 for Incident Proton Energies Noted in Column 1.

E_p (MeV)	$p + ^{16}\text{O}$	$n + ^{16}\text{F}$	$^4\text{He} + ^{13}\text{N}$	$^5\text{Li} + ^{12}\text{C}$	$^8\text{B} + ^9\text{Be}$
34	3.8	0.05	0.64	0.41	0.04
38	4.2	0.06	0.60	0.39	0.05
42	1.0	0.06	0.38	1.80	0.04

Table 2: Decay Probabilities Noted in Last Column of 396 MeV Excited ^{190}Hg to Pairs Listed in Column 1. Columns 2-3 List Q-Value, Excitation Energy (EX.EN), and Kinetic Energy (K. E) Associated With Each Pair.

Daughters	Q (MeV)	EX.EN (MeV)	K. E (MeV)	Yields
$^{94}\text{Zr} + ^{96}\text{Zr}$	141	383	154	6.7×10^{85}
$^{50}\text{Ca} + ^{140}\text{Nd}$	93	369	126	2.7×10^{84}
$^{42}\text{S} + ^{48}\text{Gd}$	61	351	115	1.0×10^{84}
$n + ^{189}\text{Hg}$	- 8.0	388	0	1.0×10^{77}